PERFORMANCE OF THE ANALOG DEVICES AD780BR VOLTAGE REFERENCE AT CRYOGENIC TEMPERATURES

Test Report

Richard Patterson
NASA Glenn Research Center

&

Ahmad Hammoud
QSS Group, Inc.

NASA Glenn Research Center
Cleveland, Ohio

March 22, 2002

PERFORMANCE OF THE ANALOG DEVICES AD780BR VOLTAGE REFERENCE AT CRYOGENIC TEMPERATURES

Background

The Analog Devices AD780 is an ultrahigh precision bandgap voltage reference that can provide a pin-programmable output of 2.5 V or 3.0 V from inputs between 4.0 V and 36 V. It can be used to improve the performance of high-resolution analog-to-digital and digital-to-analog converters due to its capacitive-load driving capability. The device is specified for operation from –40 °C to +85 °C with low temperature drift and low output noise [1]. A temperature output pin provided on the AD780 allows the device to be configured as a temperature transducer while providing a stable output reference voltage. The output of the temperature transducer, which can be used to monitor changes in the system ambient temperature, varies linearly with temperature. The AD780BR device is capable of sourcing or sinking up to 10 mA and can be used in series or shunt mode, thus allowing positive or negative output voltages without external components. The performance of plastic-packaged devices (in this case an SOIC 8 pin plastic package) at low temperatures was investigated in this work.

Test Setup

A circuit board, populated with the AD780BR and few passive components, was designed and built for evaluation in the temperature range of +25 °C to –180 °C. The device was characterized at test temperatures of 25, 0, -40, -80, -100, -120, -140, -160 and -180 °C in a liquid nitrogen cooled environmental chamber. At each test temperature, the device was allowed to soak for 15 minutes before measurements were made. Limited thermal cycle testing was also performed on the AD780BR. These tests consisted of subjecting the device to a total of ten thermal cycles between +90 °C and –125 °C at a temperature rate of 10 °C/min. Device characterization was also performed at various temperatures after completion of the thermal cycling activity.

The device performance was evaluated in terms of its 2.5 V output voltage regulation and its temperature transducer output. These characteristics were obtained using input voltages of 4, 18, and 36 volts and at three load levels. Differing resistive loads were selected so that the load current ranged between 0 and 8.33 mA. The device is specified to source or sink up to 10 mA.

Results and Discussion

Figure 1 shows the deviation in the output voltage of the device with respect to its room temperature value. The data, which is shown as a function of temperature, is depicted for all input voltage and load level combinations. It can be seen that the reference output voltage remains within specifications (2.499 to 2.501 V) between temperatures of 25 °C to –40 °C. Beyond –40 °C, however, the output voltage begins to decrease as the temperature is decreased. While this decrease in the output voltage is very minimal down to temperatures of -120 °C, it becomes more significant as the temperature is decreased further. In addition, the device exhibits unstable operation at the two extreme low temperatures; namely –160 °C and –180 °C.

Instability was also observed at the test temperature of -140 °C only when an input voltage of 4 V is applied under no load condition. It is important to note that if the output specifications were broadened to cover a range of 2.495 V to 2.501 V, the device would be useful down to temperatures of –120 °C. Table I lists all the data obtained under the various test conditions. The operating points at which the output voltage went out of specification limits and device instability occurred are shown as shaded areas in Table I.

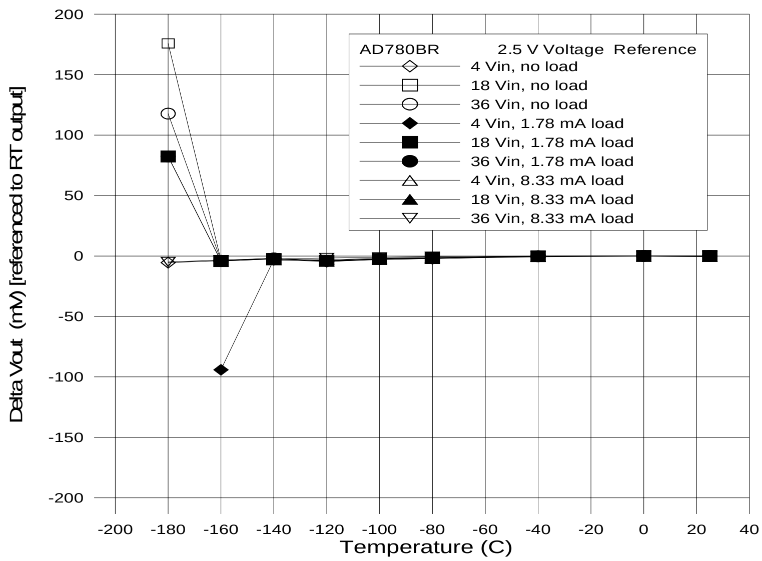

Figure 1. Deviation in the output voltage versus temperature at different test conditions.

The temperature sensor output of the AD780BR as a function of temperature is shown in Figure 2 for three different test conditions. It can be seen that for any selected input (supply) voltage, the transducer output is nearly linear with temperature for most of the range between 25 °C and –180 °C. The non-linearity seen at the extreme temperatures is due to the instability exhibited by the device, as was mentioned earlier. Data of the temperature sensor output is listed also in Table I.

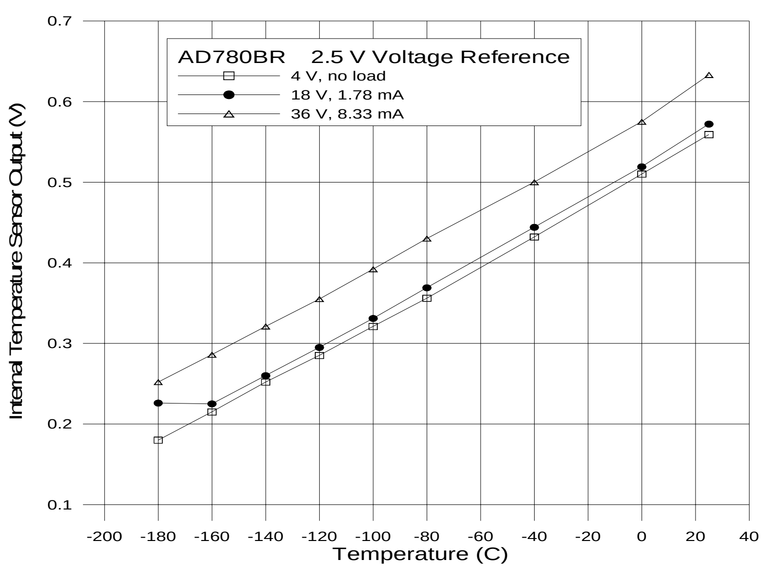

Figure 2. Temperature pin output versus temperature at different test conditions.

Table I. Results of low temperature evaluation of Analog Devices AD780BR voltage reference.

Input Voltage (V)	Output Current (mA)	Temp (°C)	Output Voltage (V)	Temp Voltage (V)
4	0	25	2.5001	.559
18	0	25	2.5001	.564
36	0	25	2.5001	.567
4	1.78	25	2.5001	.563
18	1.78	25	2.5001	.572
36	1.78	25	2.5001	.584
4	8.33	25	2.4996	.562
18	8.33	25	2.4996	.594
36	8.33	25	2.4996	.633
4	0	0	2.5001	.510
18	0	0	2.5001	.514
36	0	0	2.5001	.517
4	1.78	0	2.5001	.513
18	1.78	0	2.5001	.519
36	1.78	0	2.5001	.529
4	8.33	0	2.4999	.516
18	8.33	0	2.4999	.541
36	8.33	0	2.4999	.575
4	0	-40	2.4998	.432
18	0	-40	2.4999	.437
36	0	-40	2.4999	.441
4	1.78	-40	2.4998	.437
18	1.78	-40	2.4999	.444
36	1.78	-40	2.5000	.455
4	8.33	-40	2.4994	.439
18	8.33	-40	2.4997	.465
36	8.33	-40	2.5000	.500
4	0	-80	2.4979	.356
18	0	-80	2.4980	.359
36	0	-80	2.4982	.364
4	1.78	-80	2.4981	.361
18	1.78	-80	2.4984	.369
36	1.78	-80	2.4986	.379
4	8.33	-80	2.4980	.364
18	8.33	-80	2.4988	.390
36	8.33	-80	2.4995	.430
4	0	-100	2.4973	.321
18	0	-100	2.4974	.342
36	0	-100	2.4976	.330
4	1.78	-100	2.4978	.324
18	1.78	-100	2.4976	.331
36	1.78	-100	2.4980	.343
4	8.33	-100	2.4971	.327
Input Voltage (V)	**Output Current (mA)**	**Temp (°C)**	**Output Voltage (V)**	**Temp Voltage (V)**
18	8.33	-100	2.4980	.353
36	8.33	-100	2.4989	.392
4	0	-120	2.4955	.285
18	0	-120	2.4958	.289
36	0	-120	2.4960	.292
4	1.78	-120	2.4955	.286
18	1.78	-120	2.4961	.295
36	1.78	-120	2.4967	.306
4	8.33	-120	2.4955	.290
18	8.33	-120	2.4970	.317
36	8.33	-120	2.4984	.355
4	0	-140	2.4981	.252
18	0	-140	2.4982	.254
36	0	-140	2.4981	.258
4	1.78	-140	2.4973	.251
18	1.78	-140	2.4976	.260
36	1.78	-140	2.4976	.272
4	8.33	-140	1.9386	.037
18	8.33	-140	2.4966	.283
36	8.33	-140	2.4976	.321
4	0	-160	2.4962	.215
18	0	-160	2.4965	.219
36	0	-160	2.4961	.222
4	1.78	-160	2.4060	.215
18	1.78	-160	2.4959	.225
36	1.78	-160	2.4956	.235
4	8.33	-160		
18	8.33	-160	2.0040	.040
36	8.33	-160	2.4967	.286
4	0	-180	2.4946	.180
18	0	-180	2.6759	.259
36	0	-180	2.6178	.245
4	1.78	-180	1.5670	0
18	1.78	-180	2.5824	.226
36	1.78	-180	2.5170	.209
4	8.33	-180		
18	8.33	-180	1.2795	0
36	8.33	-180	2.4951	.252

	Voltage out of specifications
	Unstable operation

After this basic characterization with temperature, the device was subjected, as mentioned earlier, to ten thermal cycles between +90 °C and – 125 °C. Measurements of the device parameters were then followed at various temperatures. The post-thermal cycling data is listed in Table II. The results obtained were in good agreement to those obtained prior to the thermal cycling. Hence, it can be concluded that this limited thermal cycling had no significant effect on the characteristics of the AD780BR voltage reference.

Table II. Post-thermal cycling results of Analog Devices AD780BR voltage reference.

Input Voltage (V)	Output Current (mA)	Temp (°C)	Output Voltage (V)	Temp Voltage (V)
4	0	25	2.5006	.558
18	0	25	2.5007	.561
36	0	25	2.5006	.574
4	1.78	25	2.5005	.559
18	1.78	25	2.5005	.567
36	1.78	25	2.5005	.603
4	8.33	25	2.5000	.562
18	8.33	25	2.5000	.594
36	8.33	25	2.5002	.651
4	0	-40	2.4999	.432
18	0	-40	2.5001	.441
36	0	-40	2.5001	.442
4	1.78	-40	2.4999	.435
18	1.78	-40	2.5000	.443
36	1.78	-40	2.5000	.450
4	8.33	-40	2.4995	.435
18	8.33	-40	2.4998	.461
36	8.33	-40	2.5000	.502
4	0	-120	2.4945	.285
18	0	-120	2.4948	.288
36	0	-120	2.4952	.294
4	1.78	-120	2.4945	.285
18	1.78	-120	2.4950	.292
36	1.78	-120	2.4958	.305
4	8.33	-120	2.4944	.289
18	8.33	-120	2.4962	.318
36	8.33	-120	2.4980	.357

Input Voltage (V)	Output Current (mA)	Temp (°C)	Output Voltage (V)	Temp Voltage (V)
4	0	-140	2.4937	.249
18	0	-140	2.4938	.255
36	0	-140	2.4938	.259
4	1.78	-140	2.4936	.254
18	1.78	-140	2.4939	.262
36	1.78	-140	2.4942	.274
4	8.33	-140	1.9758	.060
18	8.33	-140	2.4944	.283
36	8.33	-140	2.4965	.322
4	0	-160	2.4944	.217
18	0	-160	2.4945	.220
36	0	-160	2.4942	.225
4	1.78	-160	2.4941	.218
18	1.78	-160	2.4940	.226
36	1.78	-160	2.4939	.238
4	8.33	-160	1.4200	.000
18	8.33	-160	1.9000	.064
36	8.33	-160	2.4948	.286
4	0	-180	2.4963	.18
18	0	-180	2.6200	.244
36	0	-180	2.5700	.229
4	1.78	-180	2.1200	.049
18	1.78	-180	2.5433	.217
36	1.78	-180	2.5040	.209
4	8.33	-180	0.6170	0
18	8.33	-180	1.3000	0
36	8.33	-180	2.4939	.251

(light shading)	Voltage out of specifications
(dark shading)	Unstable operation

Conclusion

The Analog Devices AD780BR is a commercial-grade, ultrahigh precision voltage reference device rated for –40 °C to +85 °C operation. The SOIC 8 pin plastic package device was evaluated for potential use in low temperature applications down to –180 °C with a 2.5 V output reference voltage. The device was characterized in terms of its output regulation and temperature sensing output in the temperature range of +25 °C to -180 °C. While the device performed well with respect to output voltage regulation with temperature down to –40 °C, the manufacturer's specified low temperature rating, it does have potential use down to –120 °C if the acceptable output is broadened to cover the range of 2.495 V to 2.501 V. With an input voltage level of 36 V, the acceptable output just mentioned can be obtained down to –160 °C. The output of the built-in temperature sensor worked well and was linear with temperature for most of the test range between 25 °C and –180 °C. No effect was observed in the operational characteristics of the device due to the applied limited thermal cycling. Further testing and long-term cycling are needed, however, to fully characterize the performance of the device and to determine its reliability for operation in low temperature environments.

References

1. Analog Devices AD780 High Precision Reference Data Sheet, Rev. B.

Acknowledgments

This work was performed under the NASA Glenn Research Center GESS Contract # NAS3-00145. Support was also provided from the NASA Electronic Parts and Packaging (NEPP) Program, EPAR Task "Electronics for Extreme Environments".